eRD17: BeAGLE

A Tool to Refine Detector Requirements for eA in the Saturation Regime

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18-Jan.-2018

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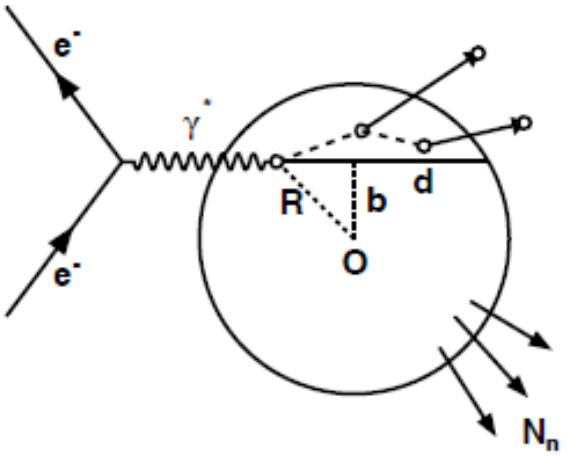
Executive summary

- What we learned: The "Lore" is Backwards!
  - Evaporation neutrons (ZDC) are NOT enough to tag coherent vs. incoherent diffraction. (from 7/2017)
  - Evaporation neutrons CAN tag collision geometry for incoherent diffraction.
- Communicating with EIC users
  - JLAB + BNL/SBU + PoETIC8-MC
- The BeAGLE project
  - Improved diffraction implementation in progress.

Key Features of BeAGLE



Multistep process.

Hard interaction (DIS or diffractive) involving one or more nucleons.

Intra Nuclear Cascade w/ Formation Zone

Excited nuclear remnant will decay:
Fission &/or evaporation of nucleons
De-excitation by gamma emission.

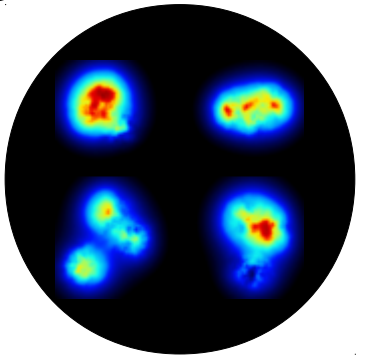
Reasonable model of both hard process AND nuclear interaction.

Improvements (already) from white paper diffraction studies:

More correct (lower) value of $<E_{exc}>$

Added b-dependence of E_{exc}, increasing fluctuations.

Incoherent diffraction as physics



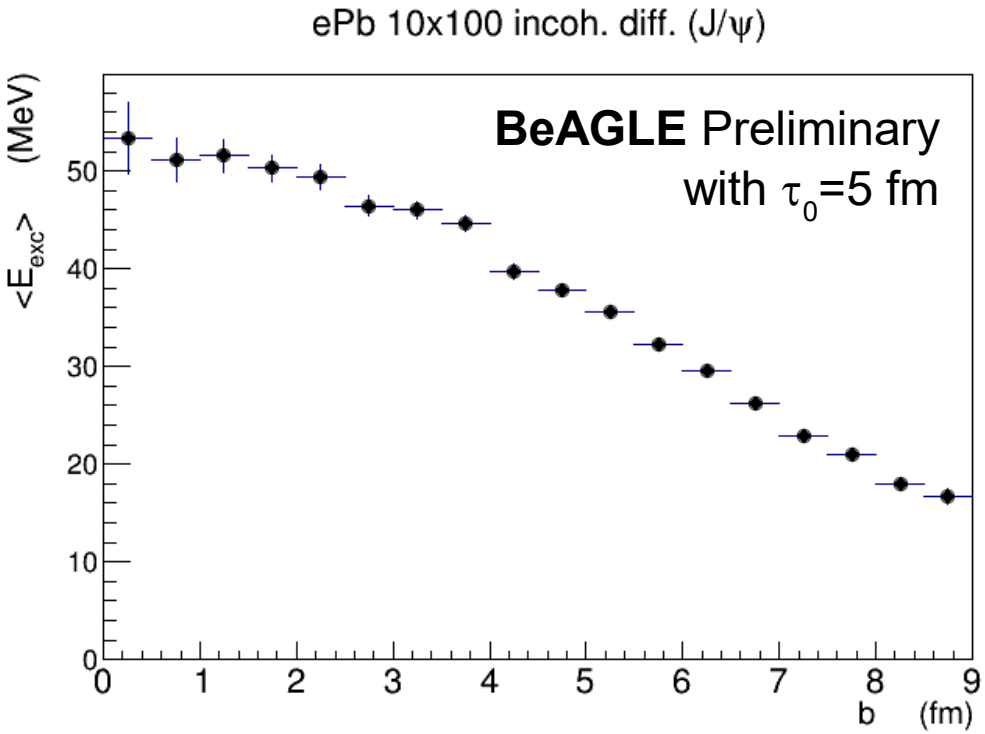
*

- Sensitive to shape fluctuations
  - We already see "hot spots" in the proton
  - Are these the same inside a nucleus?
- Geometry tagging of incoherent events?
  - Are nucleon shapes in the middle of the nucleus different than those at the edges?
  - LORE: Can't be done with evaporation neutrons becuase the excited nucleus "forgets" history.

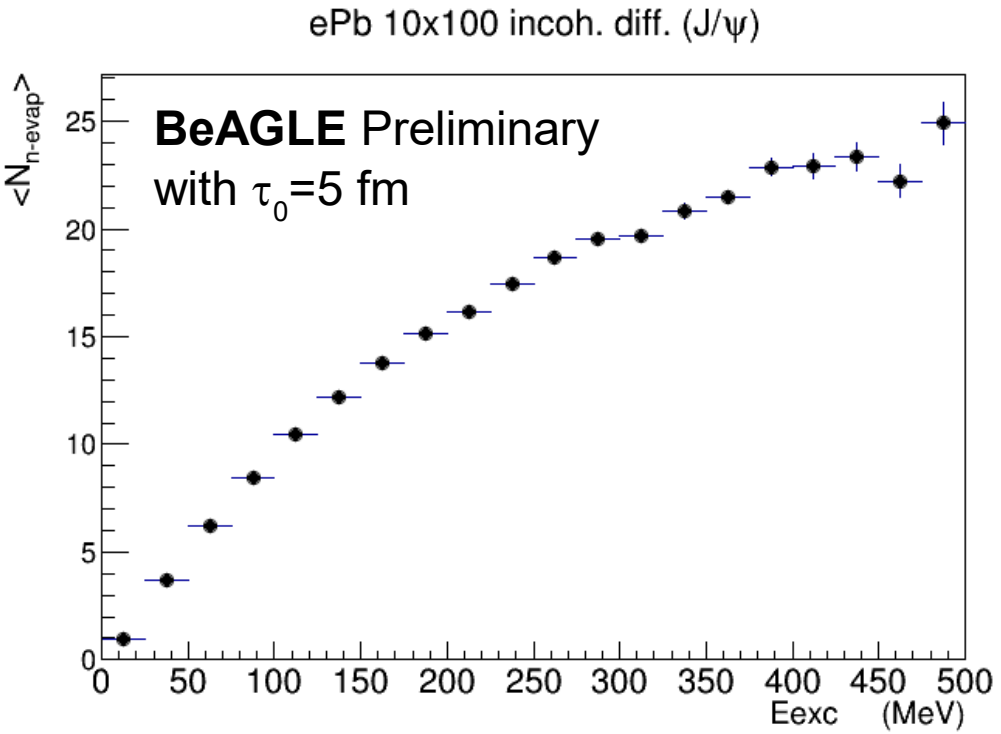
* - Example theoretical proton fluctuation configuration tuned to match ep incoherent diffractive data - from B. Schenke

The nucleus remembers!

Energy conservation!

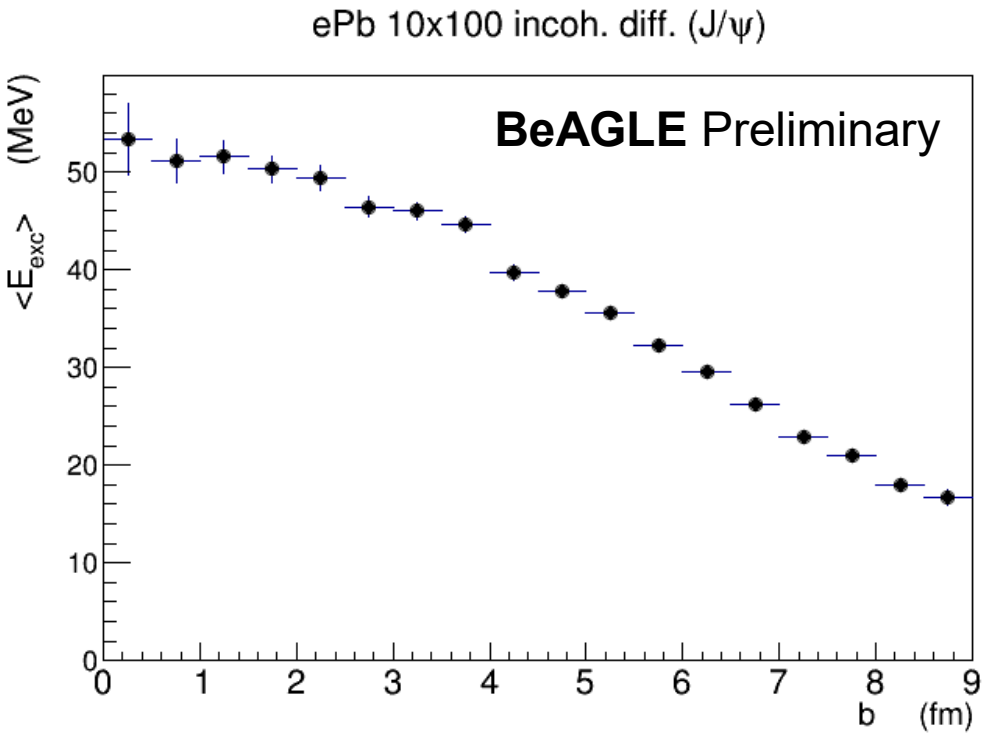


Central diffractive events excite the nucleus more than peripheral.

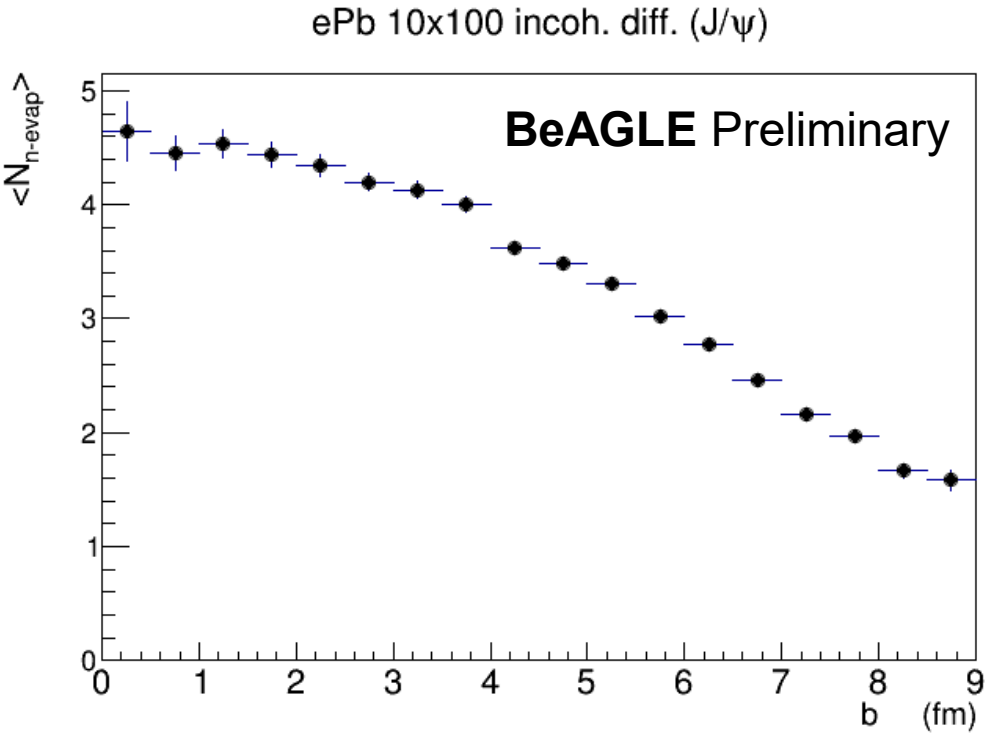


The hotter (more excited) remnant nuclei emit more evaporation neutrons – which we can detect!

ZDC & impact parameter correlated



Central diffractive events excite the nucleus more than peripheral.



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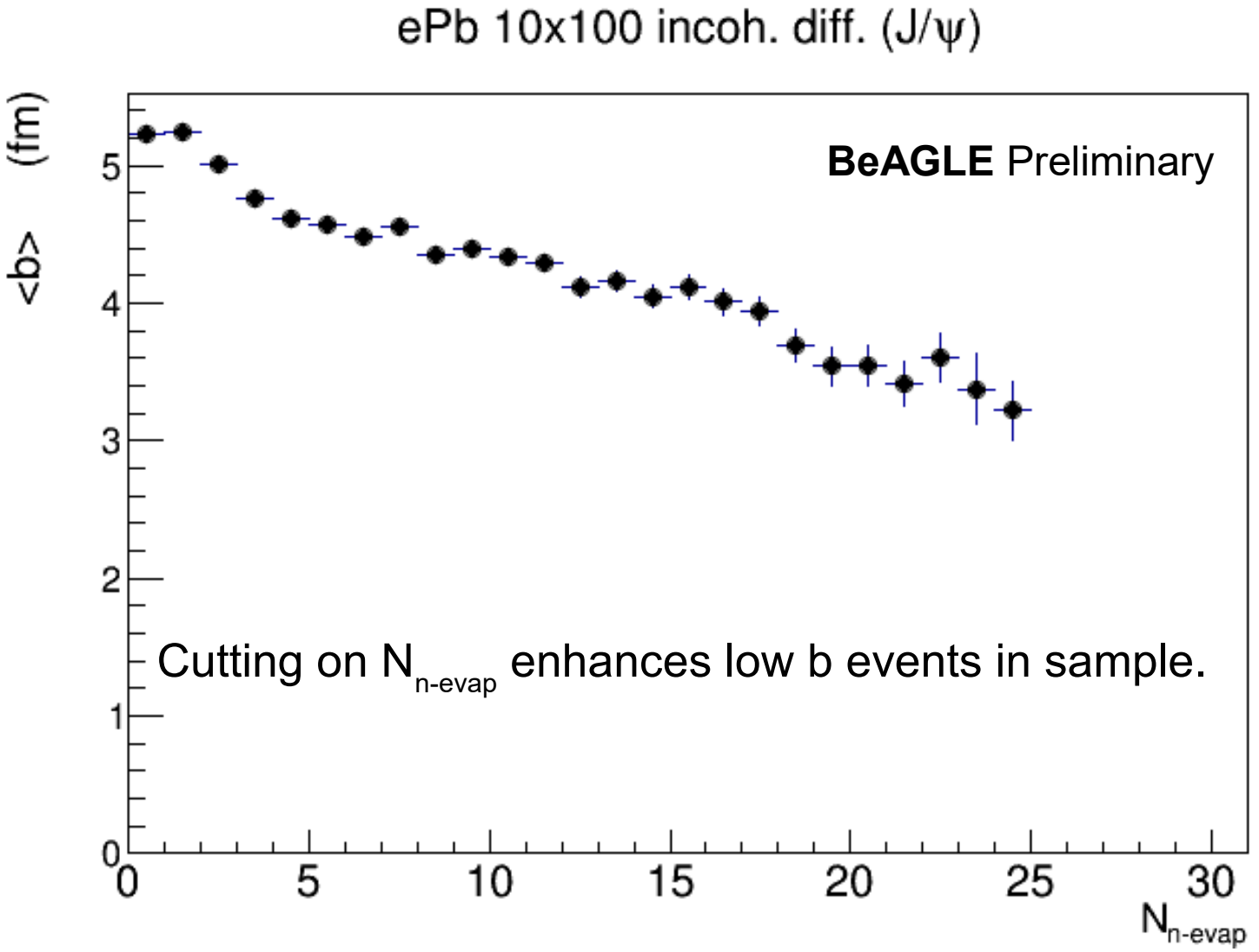
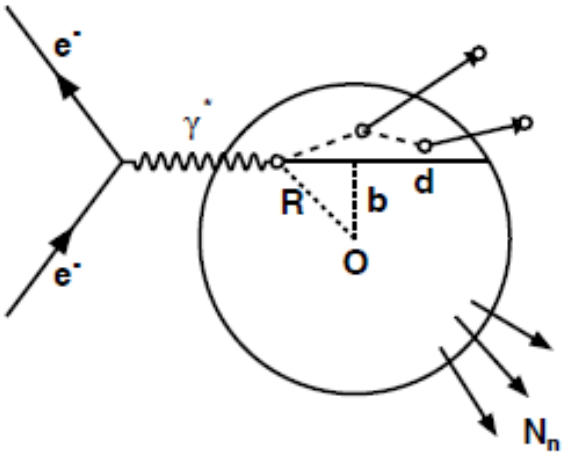
ZDC can tag impact parameter!



A paradox ?



Incoherent diffraction:

How can the ZDC do:

a GOOD job at geometry tagging

but a BAD job at vetoing?

The # of evaporation neutrons is much smaller (on average) for peripheral than central events.

So we can tell them apart.

But some peripheral events slip by w/ $N_{nevap}=0$!

Still following your advice

From the July 2015 EIC R&D Committee Report:

Recommendation: …
The committee encourages regular interaction between the developer[s] and the expected user community.

July 2017: Special Nuclear Physics Seminar (JLAB)
Dec. 2017: Center for Frontiers in Nuclear Science Seminar (SBU/BNL)
Mar. 2018: Physics Opportunities at an ElecTron-IonCollider 8 (POETIC8) Satellite workshop: MCEGs for future ep and eA facilities (Regensberg, Germany)

Note: Also starting work on a PRD (Elke & Liang taking the lead).

Fermi momentum & eN collision W^2

BeAGLE (& DPMJET & Pythia) use on-mass-shell nucleons
which sit in a mean-field nuclear binding + Coulomb potential.

In nuclear target rest frame:

$Q^{\mu} = \{\nu; 0, 0, \mathrm{sqrt}(\nu^2+Q^2)\}$ defined by lepton – nuclear kinematics

$P^{\mu} = \{M; 0, 0, 0\}$ OR $\{M+E_{kF}; p_{xF}, p_{yF}, p_{zF}\}$

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$W^2 = (P+Q)^2 = 2M\nu - Q^2 + M^2$ $(+2\nu E_{kF} - 2\mathrm{sqrt}(\nu^2+Q^2)p_{zF})$

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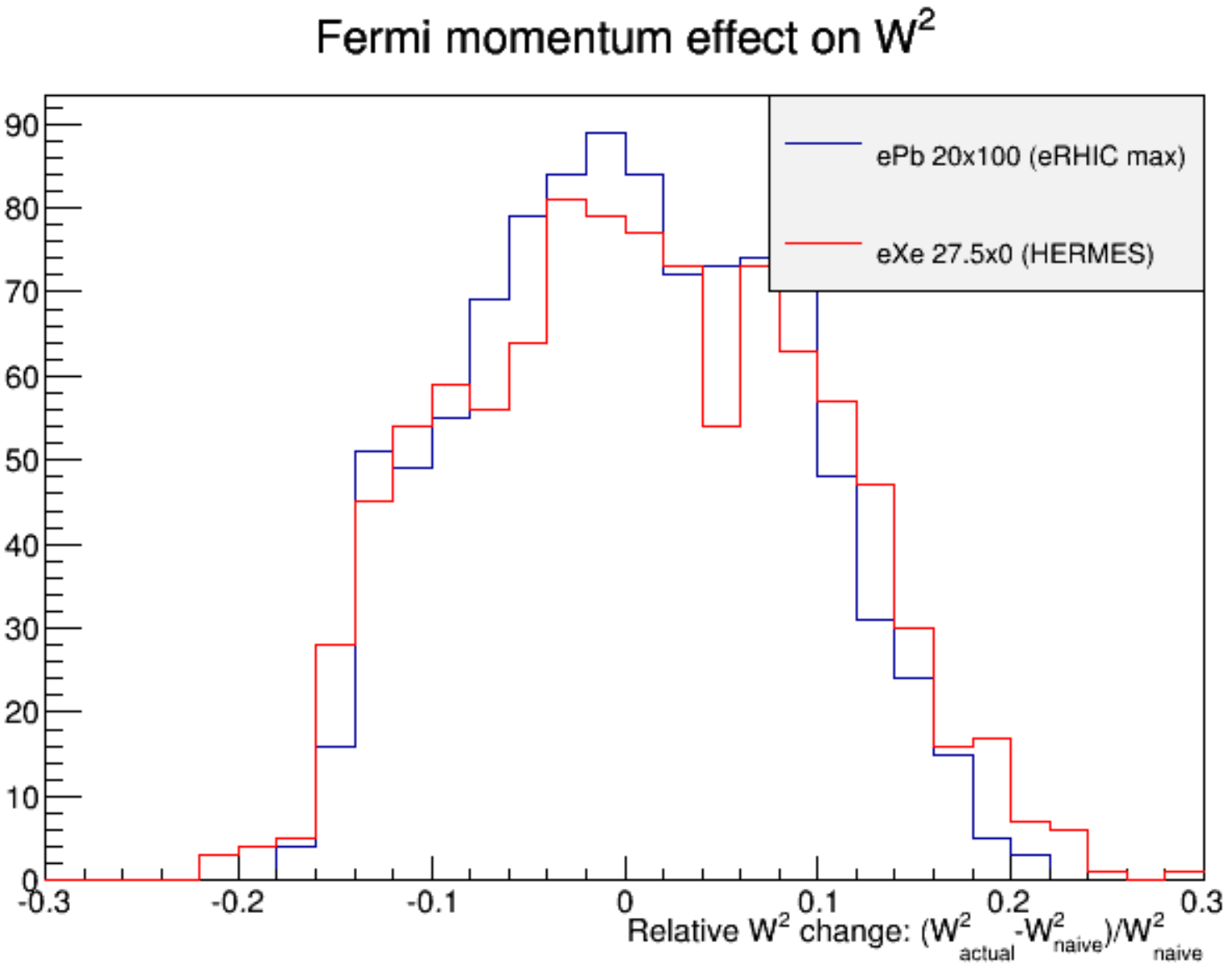
High ν limit ($\nu >> M,Q$):

$W^2 \sim 2M\nu\,(1 - p_{zF}/M)$ (note that $E_{kF} << p_{zF}$)

W^2 smearing for two extremes



rms 8%

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Updated table format

The past is prologue!

Feature added or error corrected	DPMJet Hybrid	BeAGLE 1/2017	BeAGLE 6/2017	BeAGLE 7/2017	BeAGLE (planned)
1. Hard processes correct.	YES	YES	YES	YES	YES
2. Tuned to ZEUS ep→p+X data	YES	YES	YES	YES	YES
3. IntraNuclear Cascade	YES	YES	YES	YES	YES
4. Nuclear evaporation/breakup	YES	YES	YES	YES	YES
5a. Multinucleon shadowing	NO	YES	YES	YES	YES
5b. Debug multinucleon shadow.	NO	NO	YES	YES	YES
6a. Correct nucleon remnant (n/p)	NO	YES	YES	YES	YES
6b. Debug M_n vs. M_p	NO	NO	YES	YES	YES
7. Correct eA target rest frame	NO	YES	YES	YES	YES
8. Tuned to E665 μPb→n+X data	YES	YES/NO	YES	YES	YES
9. Shadowing coherence length	NO	NO	NO	NO	YES
10. Partial shadowing effect	NO	NO	NO	YES	YES
11. Process-specific A dependence	NO	NO	Next Year	Next Year	FY2018
12. Tuned to more E665 μA data	NO	NO	Progress	Progress	FY2019
13. FS p_F for hard process correct	NO	NO	NO	NO	YES

From July 2017 meeting

Feature added or error corrected	BeAGLE 07/2017	BeAGLE 12/2017	BeAGLE (planned)
1-8. Early BeAGLE features (see text)	YES	YES	YES
9. Shadowing coherence length	NO	NO	YES
10. Partial shadowing effect	YES	YES	YES
11a. Effective σ_{dipole} for J/ψ averaged over x & Q^2	YES	YES	YES
11b. Effective σ_{dipole} for ϕ averaged over x & Q^2	NO	YES	YES
11c. Eff. $\sigma_{dipole}(x,Q^2)$ for V=ψ,ϕ,ρ,ω from Sartre (ePb)	NO	NO	YES
11d. Use correct $R_{diff}^{(A=208)}(x,Q^2)$ for V from Sartre	NO	NO	YES
11e. Improved σ_{dipole} for V, if necessary	NO	NO	YES
12. Tune to E665 μA Streamer Chamber data	NO	NO	YES
13. FS p_F for hard process correct	NO	(Testing)	YES
14. Kinematic matching between DPMJet&Pythia	NO	YES	YES
15. Protect against very high E_{exc} values.	NO	YES	YES
16. Enable nPDF with any value of A,Z (EPS09)	NO	YES	YES
17. Extend R→ σ_{dipole} map to more values of A	NO	NO	YES
18. Tune the t distribution for multiple scattering.	NO	NO	YES
19a-c. Install, test, & release BeAGLE/RAPGAP	NO	NO	YES
20. Implement UltraPeripheral Photon Flux	NO	NO	YES
21. Tune BeAGLE to UPC data (RHIC &/or LHC)	NO	NO	YES

Table 1. Technical accomplishments and plans through FY2019.

Progress since last meeting

Feature added or error corrected	BeAGLE 07/2017	BeAGLE 12/2017	BeAGLE (planned)
1-8. Early BeAGLE features (see text).	YES	YES	YES
9. Shadowing coherence length	NO	NO	YES
10. Partial shadowing effect	YES	YES	YES
11a. Effective σ_{dipole} for J/ψ averaged over x & Q^2	YES	YES	YES
11b. Effective σ_{dipole} for ϕ averaged over x & Q^2	NO	YES	YES
11c. Eff. $\sigma_{dipole}(x,Q^2)$ for V=ψ,ϕ,ρ,ω from Sartre (ePb)	NO	NO	YES
11d. Use correct $R_{diff}^{(A=208)}(x,Q^2)$ for V from Sartre	NO	NO	YES
11e. Improved σ_{dipole} for V, if necessary	NO	NO	YES
12. Tune to E665 μA Streamer Chamber data	NO	NO	YES
13. FS p_F for hard process correct	NO	(Testing)	YES
14. Kinematic matching between DPMJet&Pythia	NO	YES	YES
15. Protect against very high E_{exc} values.	NO	YES	YES
16. Enable nPDF with any value of A,Z (EPS09)	NO	YES	YES
17. Extend R$\rightarrow$ σ_{dipole} map to more values of A	NO	NO	YES
18. Tune the t distribution for multiple scattering.	NO	NO	YES
19a-c. Install, test, & release BeAGLE/RAPGAP	NO	NO	YES
20. Implement UltraPeripheral Photon Flux	NO	NO	YES
21. Tune BeAGLE to UPC data (RHIC &/or LHC)	NO	NO	YES

Table 1. Technical accomplishments and plans through FY2019.

Target dates

Feature added or error corrected	BeAGLE 07/2017	BeAGLE 12/2017	BeAGLE (planned)	
1-8. Early BeAGLE features (see text).	YES	YES	YES	
9. Shadowing coherence length	NO	NO	YES	Delayed. Not urgent.
10. Partial shadowing effect	YES	YES	YES	
11a. Effective σ_{dipole} for J/ψ averaged over x & Q^2	YES	YES	YES	
11b. Effective σ_{dipole} for ϕ averaged over x & Q^2	NO	YES	YES	
11c. Eff. $\sigma_{dipole}(x,Q^2)$ for V=ψ,ϕ,ρ,ω from Sartre (ePb)	NO	NO	YES	FY2018
11d. Use correct $R_{diff}^{(A=208)}(x,Q^2)$ for V from Sartre	NO	NO	YES	FY2018
11e. Improved σ_{dipole} for V, if necessary	NO	NO	YES	FY2018
12. Tune to E665 μA Streamer Chamber data	NO	NO	YES	FY2019
13. FS p_F for hard process correct	NO	(Testing)	YES	Delayed. Almost ready.
14. Kinematic matching between DPMJet&Pythia	NO	YES	YES	
15. Protect against very high E_{exc} values.	NO	YES	YES	
16. Enable nPDF with any value of A,Z (EPS09)	NO	YES	YES	
17. Extend R$\rightarrow$ σ_{dipole} map to more values of A	NO	NO	YES	FY2018
18. Tune the t distribution for multiple scattering.	NO	NO	YES	FY2018
19a-c. Install, test, & release BeAGLE/RAPGAP	NO	NO	YES	**FY2018: β by July**
20. Implement UltraPeripheral Photon Flux	NO	NO	YES	FY2019
21. Tune BeAGLE to UPC data (RHIC &/or LHC)	NO	NO	YES	FY2019

Table 1. Technical accomplishments and plans through FY2019.

FY2018 milestones

- FY2018 – improve diffractive description
  - Qtr1: Process-dependent cross-section:
    - (eN) diffractive events =(incoherent eA) are different than DIS in A-dependence and in multinucleon shadowing
  - RAPGAP in BeAGLE (as Pythia alternative)
    - Qtr2: Alpha release (code runs without crashing and results aren't obviously nuts)
    - Qtr3: Beta release (code appears to work but needs more testing)

JULY 2018

    - Qtr4: Release – ready for prime time

External Funding

- Salaries from home institutions:
  E. Aschenauer, J.H. Lee, L. Zheng
- JLAB LDRD: Geometry Tagging at JLEIC
  A. Accardi, M.D. Baker, R. Dupre, M. Erhart,
  C. Fogler, C. Hyde, V. Morozov (PI),
  P. Nadel-Turonski, K. Park, A. Sy, T. Toll,
  G. Wei, L. Zheng

Liang Zheng

- Project focus currently on writing a paper (PRD)
- Just starting new duties as an Asst. Professor.
  - China University of Geosciences (Wuhan)
- Students may join us in Fall 2018.
- Liang ready to travel in Summer 2019.
  - Travel funds in FY2019 proposal?

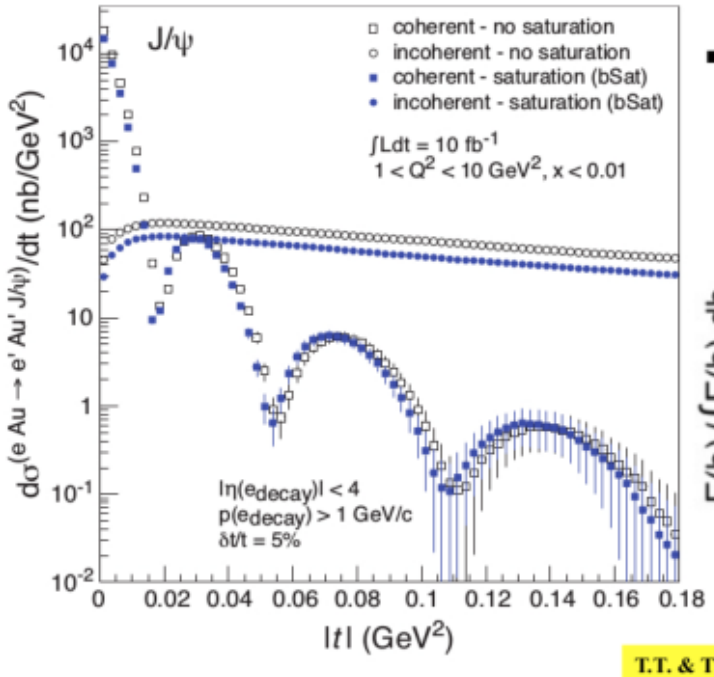
Conclusion

- The "Lore" is Backwards!
  - Evaporation neutrons (ZDC) are NOT enough to tag coherent vs. incoherent diffraction. (from 7/2017)
  - Evaporation neutrons CAN tag collision geometry for incoherent diffraction.
- Communicating with EIC users
  - JLAB + BNL/SBU + PoETIC8-MC
- The BeAGLE project
  - Improved diffraction implementation in progress.

Extras

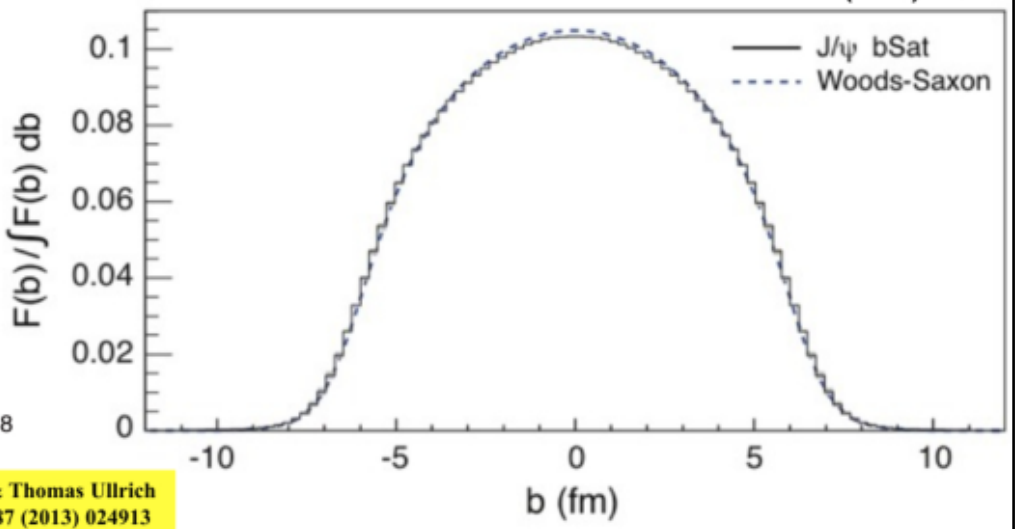
Probing the spatial gluon distribution at EIC

Momentum transfer t conjugate to transverse coordinate b



$$F(b) \propto \int \mathrm{d}\Delta \Delta J_0(\Delta b) \sqrt{\frac{\mathrm{d}\sigma}{\mathrm{d}t}}$$

$t = \Delta^2/(1-x) \approx \Delta^2$

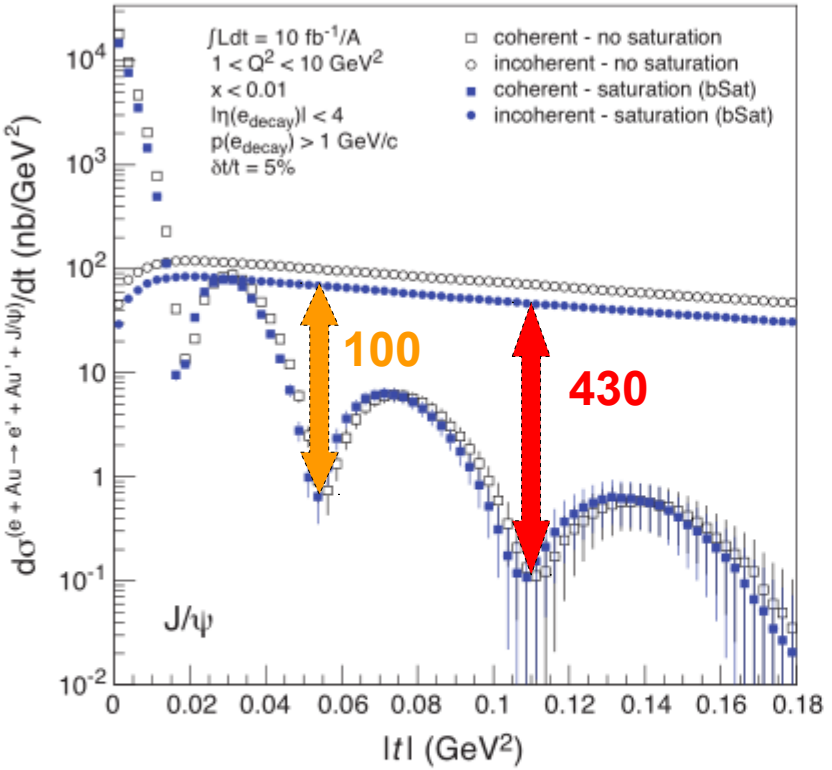


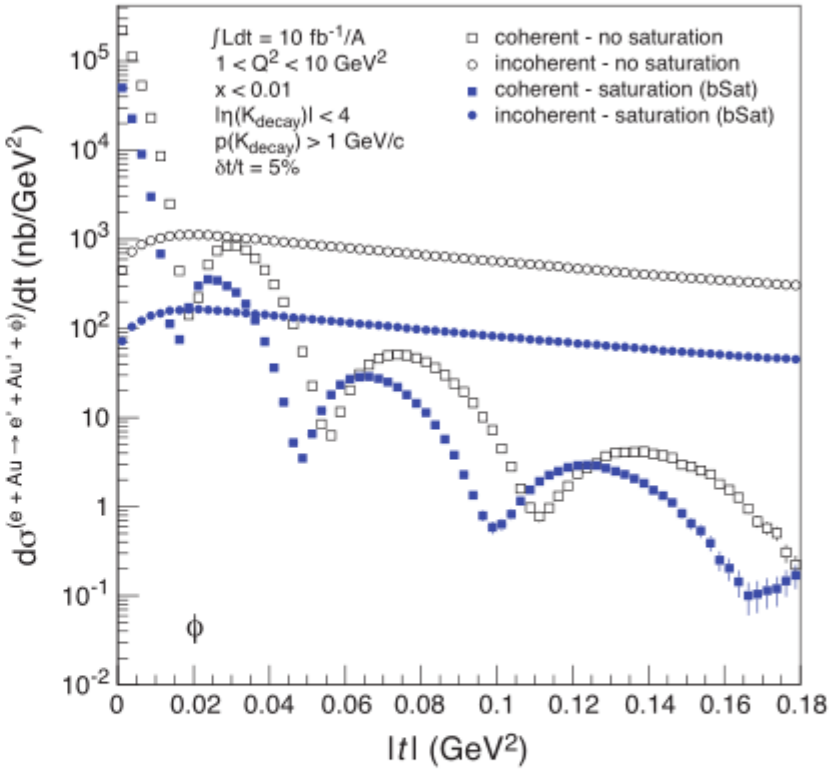
T.T. & Thomas Ullrich
PRC 87 (2013) 024913

EIC will be able to retrieve the spatial gluon distribution with high precision.

IF we can extract the coherent diffraction pattern

Starting Point



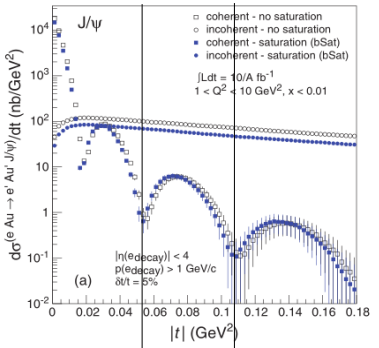


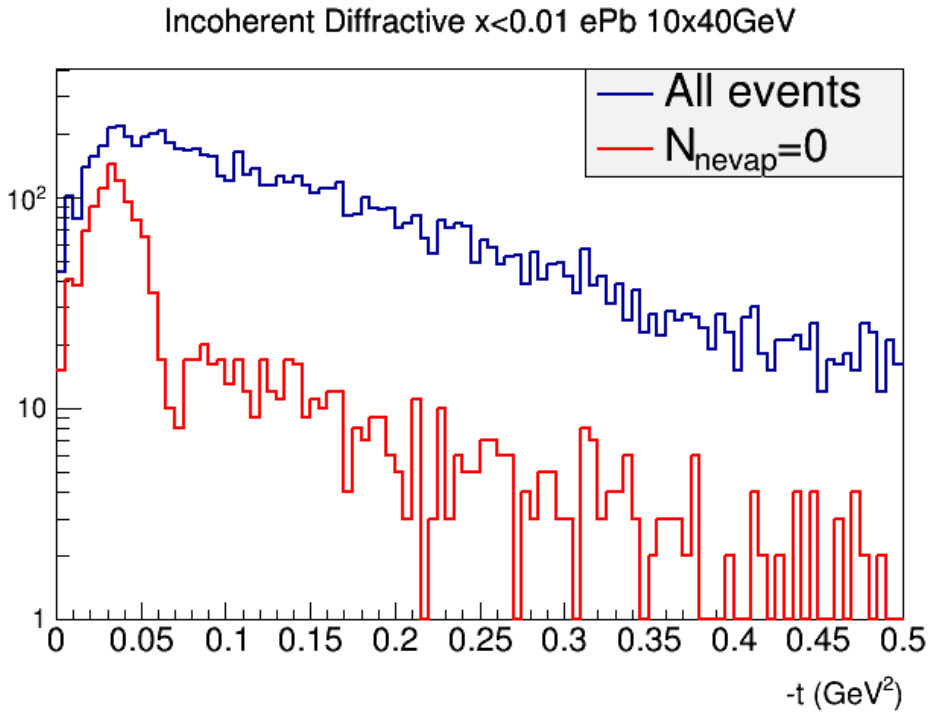
Reminder:

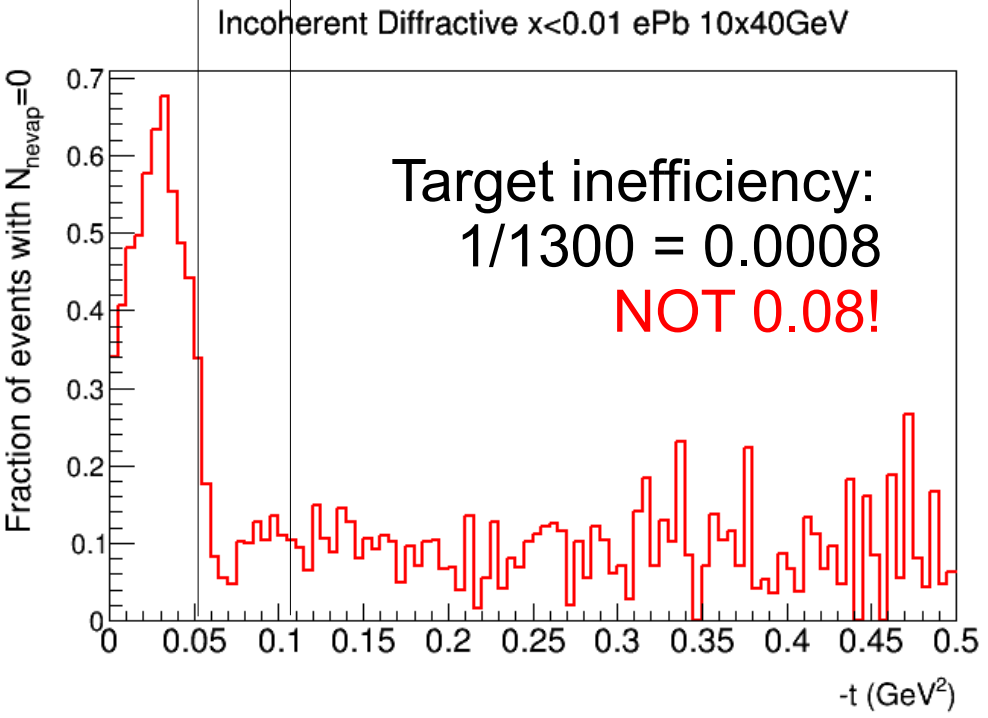
Toll, Ullrich PRC 87 (2013) 024913

- e + Au → e' + Au + J/ψ: not sensitive to sat. effects
- e + Au → e' + Au + ϕ: larger wf ⇒ sensitive to sat. effects
- Sartre: uses Woods-Saxon to generate nuclei

N_{nevap} veto inefficiency







Incoh. diffraction is also interesting!

Workshop: Synergies of pp and pA Collisions with an EIC, BNL 2017-06-26

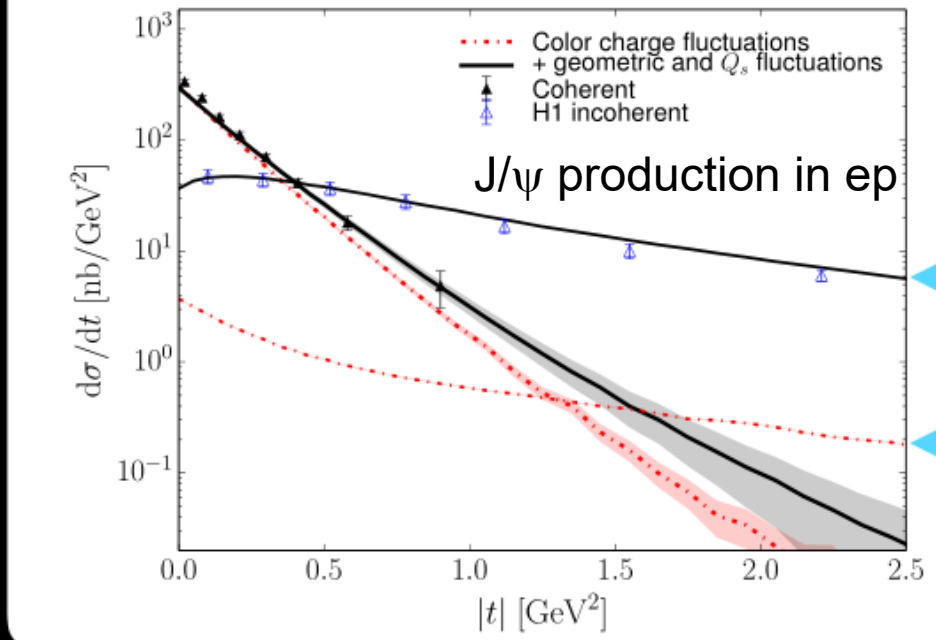
IP-Glasma results

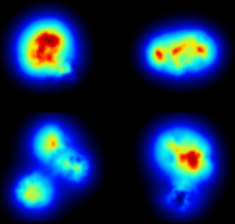
H. Mäntysaari, B. Schenke, Phys. Rev. Lett. 117 (2016) 052301; Phys.Rev. D94 (2016) 034042

Geometric + color charge fluctuations

Wilson lines

Dipole amp.: $N(\vec{r}, x_{\mathbb{P}}, \vec{b}) = N(\vec{x}-\vec{y}, x_{\mathbb{P}}, (\vec{x}+\vec{y})/2) = 1 - \mathrm{Tr} V(\vec{x}) V^{\dagger}(\vec{y})/N_c$





tuned shape fluctuations

round proton

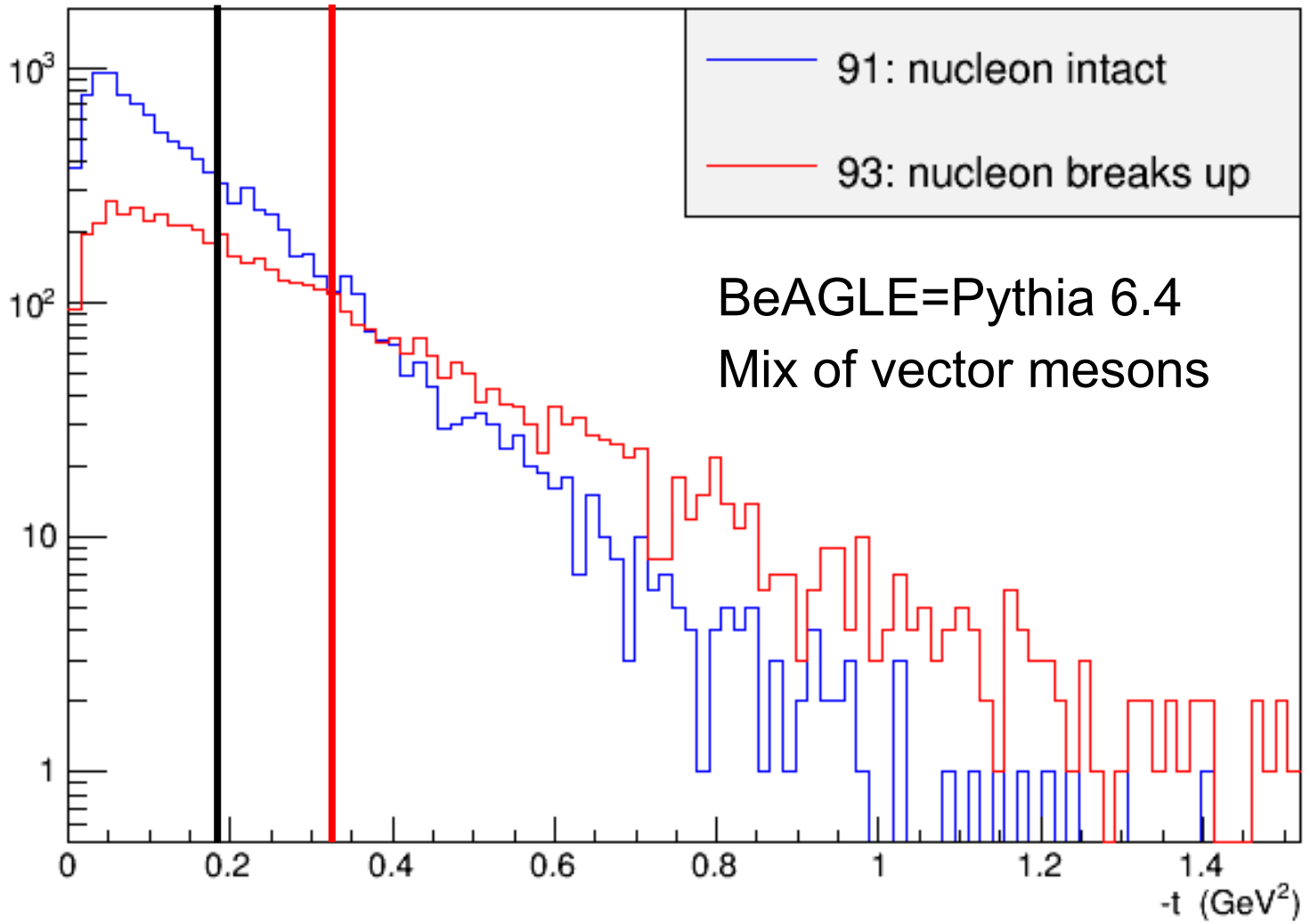
H1 Collaboration, Eur. Phys. J. C73 (2013) no. 6 2466

10

Björn Schenke, BNL

eN diffraction: $\gamma^*+N \rightarrow V+N \rightarrow V+X$

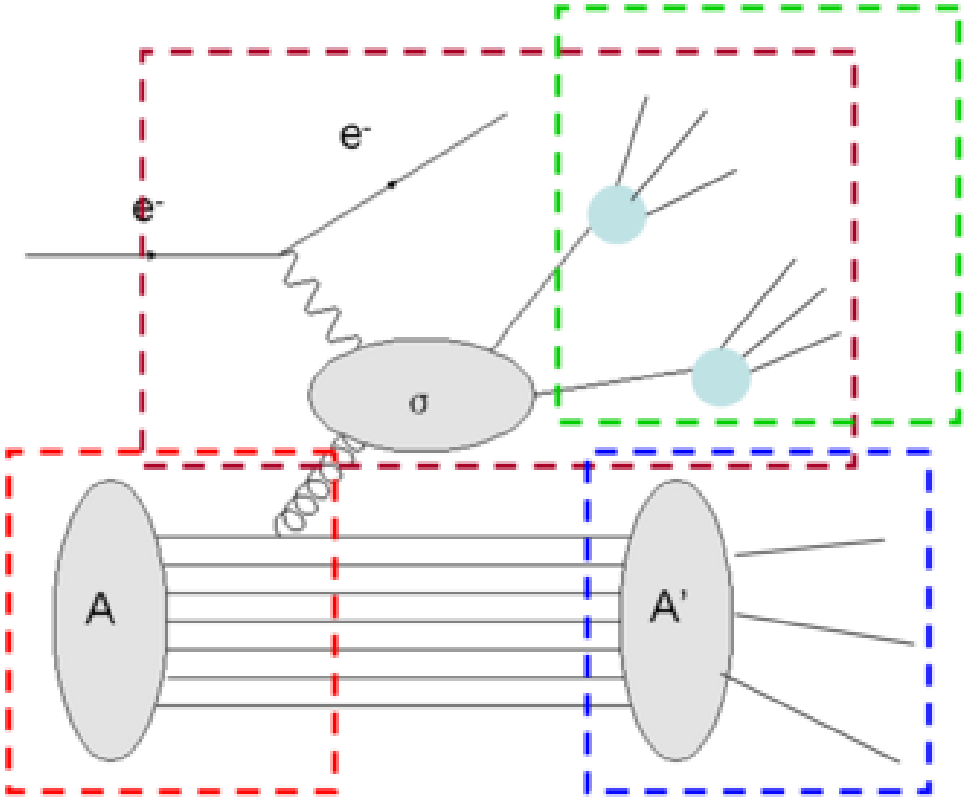
Nucleon usually stays intact for $|t|<0.33$ GeV^2



BeAGLE Structure

Elke Aschenauer + MDB + J.H.Lee + Liang Zheng

From: https://wiki.bnl.gov/eic/index.php/BeAGLE



A hybrid model consisting of DPMJet and PYTHIA with nPDF EPS09.

Nuclear geometry by DPMJet and nPDF provided by EPS09.

Parton level interaction and jet fragmentation completed **in Pythia**

Intra Nuclear Cascade &
Nuclear evaporation (gamma dexcitation/nuclear fission/fermi break up) treated by DPMJet **(Fluka)**

Energy loss effect from routine by **Accardi, Dupré** Salgado&Wiedemann to simulate the nuclear fragmentation effect in cold nuclear matter **is available.**